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FIDELITY OF NORTHERN PINE SNAKES (*Pituophis m. melanoleucus*) TO NATURAL AND ARTIFICIAL HIBERNATION SITES IN THE NEW JERSEY PINE BARRENS

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Environmental managers require information on whether human-made hibernacula are used by rare snakes before constructing large numbers of them as mitigation measures. Fidelity of northern pine snakes (*Pituophis m. melanoleucus*) was examined in a 6-year study in the New Jersey Pine Barrens to determine whether they used natural and artificial hibernacula equally. Pine snakes used both artificial (human-made) and natural (snake-adapted) hibernacula. Most natural hibernacula were in abandoned burrows of large mammals. Occupancy rates were similar between natural and artificial hibernacula. Only 6 of 27 radio-tracked snakes did not shift hibernacula between years, whereas 78% shifted sites at least once, and fidelity from one year to the next was 42%. For snakes that switched hibernacula ($n = 21$), one switched among artificial hibernacula, 14 (65%) switched among natural hibernacula, and 6 (29%) switched from artificial to natural hibernacula. Data indicate that most pine snakes switch among hibernacula, mainly selecting natural hibernacula, suggesting that artificial dens are used, but protecting natural hibernacula should be a higher conservation priority.

Snakes adapt to cold winter temperatures by hibernating, and where suitable sites are limited, they may hibernate communally (Harvey and Weatherhead, 2006). A hibernaculum is defined as any underground structure or subterranean location below the frost line that free-roaming snakes select as a winter refuge (Zappalorti and Reinert, 1994). Snakes hibernate in a variety of places, including rocky talus slopes (Clark et al., 2008), limestone crevices (White and Lasiewski, 1971), and underground abandoned mammal burrows (Burger et al., 1988). Where suitable hibernation sites are limited, fidelity to a given site may develop, especially when key overwintering habitat features are patchily distributed and difficult to locate (Reed et al., 2012). Knowing the relationship between the overall use of hibernation sites and fidelity by individuals is essential for understanding snake ecology, which enables better conservation decisions (Burger and Zappalorti, 2011a). Natural snake hibernacula, located in suitable but limited habitat, are especially important to conserve and protect snake populations. When natural hibernacula are destroyed by development, artificial ones are often made to provide places to overwinter. Environmental managers,

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however, need to know whether snakes readily use these constructed sites, and whether they are used less often than natural hibernacula.

The present study examined use of natural and artificial hibernation sites by northern pine snakes (*Pituophis melanoleucus*) over a 6-year period in Stafford Township, Ocean County, New Jersey. Questions addressed were: (1) What sites were used by pine snakes as natural hibernacula? (2) Did snakes exhibit fidelity to hibernacula? (3) Did fidelity in individual snakes vary by type of hibernacula (natural or artificial)? This study is unique in that it compares snake choice of natural versus artificially constructed hibernacula, an issue of some concern to environmental managers.

Preferred hibernation sites of pine snakes are typically in open areas with some sun penetration to the ground, features that may be limited due to the homogeneous pine/oak forest canopy that dominates the Pine Barrens landscape (Burger et al., 1988; Burger and Zappalorti, 2012). In previous studies in a different part of the New Jersey Pine Barrens, Burger and Zappalorti (2012) demonstrated that northern pine snakes occupied the same hibernacula over a 26-year period, and also showed philopatry to nest sites (Burger and Zappalorti, 1992). Some individuals used the same hibernacula continuously, and others moved to different hibernacula, often returning to the original one in subsequent years.

New Jersey is the most densely populated state in the United States, and pine snakes have lost habitat at the rate of 0.29% a year (Hasse and Lathrop, 2008; Golden et al., 2009). Pine snakes are listed as a threatened species in New Jersey, but developers continue to challenge the pine snake's status, wishing to remove them from the state list (Burger and Zappalorti, 2012). After emerging from hibernation, pine snakes use a variety of habitats (i.e., pitch-pine-dominated forests, open grassy fields and pine–oak forests, and forested wetlands; Burger and Zappalorti, 1988a, 1988b; Woodward and Barthalmus, 1996). Snakes dig their own nests and modify other sites to use as hibernacula (Carpenter, 1982). Much of the conservation concern for the species involves hibernation sites, and whether artificial (human-made) ones are suitable and equally preferred to natural hibernacula.

METHODS

The study was conducted at Stafford Forge Wildlife Management Area (WMA; 4,832.29 ha, 11,931.59 acres) in Ocean County, New Jersey. The overall protocol involved examining hibernacula use and fidelity by 27 adult radio-tracked pine snakes, some of which were translocated to the WMA from a nearby property. Prior to translocation, three management fields were made that measured 300 ft by 800 ft (90 m × 240 m; 5.5 acres) for pine snakes within the WMA, following the design of Zappalorti and Reinert (1994) and Zappalorti and Golden (2006). Two artificial hibernacula were constructed on each management field, approximately 350 ft (106 m) apart (Zappalorti and Reinert, 1994). Earthen berms and log piles were constructed to provide basking habitats, and open patches of sand were left for pine snake nesting (Burger and Zappalorti, 1991; Beane and Pusser, 2007). Warm-season grasses were planted to provide forage for small mammals and ground-nesting birds (Zappalorti and Golden, 2006). In September 2006, 100 pine snakes (25 adults, 4 subadults, and 71 hatchlings), were divided into 6 equal groups and released into corralled enclosures with one artificial hibernaculum. The fences ensured that snakes were forced to overwinter in an artificial hibernaculum.

Hatchlings and subadults were injected with passive integrated transponders (PIT), tags for future identification (Elbin and Burger, 1994), and all 25 adults were surgically implanted with radio transmitters following the procedure of Reinert and Cundall (1982) and Reinert (1992). In April 2007, 9 adults with transmitters, 2 juveniles, and 35 hatchling pine snakes (48%) were released into the forest. During the 2007 field seasons, an additional 18 unmarked resident adult pine snakes were captured in the study area. These snakes were also surgically implanted with radio transmitters

made by Advanced Telemetry Systems (Isanti, MN, model R1536), with a weight of 27 g and a battery life of 897 days. Properly inserted transmitters do not affect health or behavior of snakes (Reinert, 1992, 1993). During April 2008, the remaining 54 snakes (16 adults with transmitters, 2 juveniles, and 36 hatchling pine snakes [52%]) were released from the corrals. By year 6, road mortality, forest fire, and predation accounted for the death of 26 pine snakes. Thus, in this article hibernacula use and fidelity by 27 adult radio-tracked pine snakes captured at least one additional time is reported.

During the active warm season (April–October), snakes with radio transmitters were located every 48 h. During the winter (November–March), the radio-tracked snakes were checked once a month while hibernating. As a result of tracking free-roaming pine snakes over 6 years, natural hibernacula were discovered in stump holes or in small or large mammal burrows ($n = 45$). The results reported in this study reflect (1) 27 radio-tracked pine snakes (9 that were translocated and 18 that were captured on site), and (2) 100 snakes that were translocated. Fidelity is reported in two ways: (1) for individual snakes (over the 6-year study), and (2) as the percent of time snakes used a given den from one year to the next. These two methods account for individual snake fidelity (where a radio-tracked snake could be followed for multiple years), as well as fidelity from one year to the next (where all 2-year dyads were analyzed). The second method allows comparison with other studies of fidelity, which were conducted only over a 2- or 3-year period (e.g., Gerald et al., 2006a, 2006b). Previous studies indicated that handling pine snakes did not affect their subsequent behavior (Burger and Zappalorti, 2011b). Statistical differences were determined by chi-squared tests (Statistical Analysis Systems, Inc. [SAS], 2005).

RESULTS

Habitat Use in Natural Hibernacula

In the first year (2006–2007), all 100 translocated snakes were forced to overwinter in the artificial hibernacula. In April 2007, 46 pine snakes (48%) were released into the forest. In the second year (2007–2008), all remaining pine snakes (52%) were released from the corrals. Thereafter, snakes either could use artificial hibernacula, or could find and hibernate in natural hibernacula. Snake use of hibernation sites varied by type (Figure 1, $\chi^2 = 16.6$, df $= 2$, $p < .0008$). Most snakes used abandoned burrows of large mammals (coyote [*Canis latrans*], fox [*Vulpes fulva*], woodchuck [*Marmota monax*]), followed by excavating down old stump holes and using abandoned small mammal burrows (skunk [*Mephitis mephitis*], red squirrel [*Tamiascurus hudsonicus*], chipmunk [*Tamias striatus*]). After two winters (2006 to 2008), only 14% of the occupancies of the 100 translocated snakes were in the artificial hibernacula. There were only 6 artificial hibernacula, but 45 natural hibernacula were located using the radio-tracked snakes. Thus, the 6 artificial hibernacula accounted for approximately 12% of known hibernacula (artificial + natural), suggesting no clear preference for natural hibernacula (χ^2 test, not significant).

Snake preferences for artificial or natural hibernacula were also examined with the use of only the 27 radio-tracked snakes. For the 6 years of the study, radio-tracked snakes used the artificial hibernacula 12% of the time. The average use of artificial hibernacula ranged from 9 to 17% per year. Data suggest

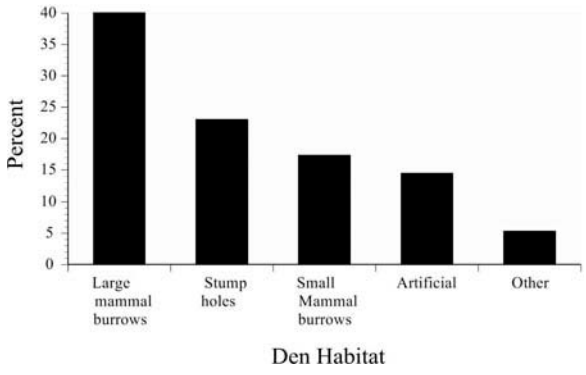

FIGURE 1. Percent of pine snakes using different types of hibernacula in the New Jersey Pine Barrens. There were 6 artificial (human-made) hibernacula and 45 natural hibernacula.

that there was not a preference for natural dens. Most of the snakes entered hibernacula with other snakes, but the precise number was unknown because hibernacula were not excavated.

Fidelity to Hibernacula

Of the 27 snakes that were radio-tracked, some were captured at the end of the study, some were found dead, and others went missing because they moved so far they could not be located (or died). Snakes could use the same hibernacula (either natural or artificial) or switch to another hibernacula (one or more times). Overall, only six radio-tracked snakes did not shift hibernacula for the number of years they were located (22% of 27 radio-tracked snakes). Thus, 21 snakes shifted sites at least once during the study period. Of the 5 snakes that were radio-tracked for all 6 years, two used the same hibernaculum for 6 years, one used 3 different hibernacula, one used 4 hibernacula, and one used 5 hibernacula (Table 1). When only considering whether a given snake exhibited fidelity to the site used the previous year (the measure usually reported in the literature), snakes showed fidelity 42% of the time.

Snakes could switch among artificial hibernacula, among natural hibernacula, or among both natural and artificial hibernacula. For snakes that switched hibernacula ($n = 21$), 1 switched among artificial hibernacula, 14 (67%) switched among natural hibernacula, and 6 (29%) switched between the 2 types (artificial to natural). Thus, individual snake fidelity was lower for artificial hibernacula ($\chi^2 = 6.9$, df $= 2$, $p < .03$).

DISCUSSION

Methodological Issues

There are several methodological issues that accompany any field study of secretive snakes, including (1) relocating snakes each year, (2) natural mortality, (3) removal by illegal collectors, and/or (4) death on roads by vehicular traffic. Some snakes, especially adult males, move away from the study area. It is not possible to know whether missing snakes died of old age, were killed by predators, or died by some other means (Burger et al., 1988). The duration of the study may influence calculation of fidelity, or may influence recapture of a given snake (Burger and Zappalorti, 2012). The study could be biased because some of the snakes were captured opportunistically, and others were trapped and translocated. Both translocated snakes and those caught within the site showed fidelity, or lack thereof, suggesting that this was not a bias.

Fidelity of Pine Snakes

Fidelity to sites for nesting and hibernating is adaptive in that animals use a known site that is presumably free from predators and meets the snakes' needs for protection and thermoregulation (Burger and Zappalorti, 2012). Site fidelity suggests that hibernation sites require protection from development, especially for threatened or endangered species.

In this study pine snakes sometimes exhibited fidelity, but others shifted hibernacula sites; some returned to the original hibernaculum a year or two later. There was no clear preference for natural over artificial hibernacula, and some snakes continued to shift even when they found

TABLE 1. Philopatry in 27 Radio-Tagged Pine Snakes as a Function of Years Tracked in the New Jersey Pine Barrens

	Tracked for 2 years	Tracked for 3 years	Tracked for 4 years	Tracked for 5 years	Tracked for 6 years	Total snakes
Number of times snake could be philopatric	1	2	3	4	5	
Number of snakes that shifted	8	5	3	2	3	21
Number of snakes that were philopatric	2	2	0	0	2	6
Number of snakes tracked for each time period	10	7	3	2	5	27

Note. A snake had to be tracked for at least 2 years to get 1 philopatry reading.

a natural hibernaculum. Initially 92 pine snakes were placed in 6 different artificial hibernacula in the fall of 2006 (ensuring they found a safe place to overwinter). In 2007, however, these snakes were free to return to one of the artificial hibernacula or to find a natural hibernaculum. Similarly in all other years, all snakes were free to return to an artificial hibernaculum, or to find a natural one. Snakes have the olfactory ability to follow chemical scent trails of conspecifics, which lead them to hibernacula (Ford, 1986; Reinert and Zappalorti, 1998; Burger, 1989; Shetty and Shine, 2000).

Overall, 78% of pine snakes shifted sites at least once during the study period. These shifts were not due to disturbance, since snakes were not disturbed while entering or leaving. Although pine snakes showed some degree of fidelity, over the 6-year period most snakes shifted hibernacula sites at least once. Shifting may be due to the natural seasonal movements of snakes. During fall movements, if the weather turns cold, they may be forced to enter any nearby hibernaculum. Further, natural hibernacula may become less suitable because they are invaded by small mammals, such as short-tailed shrews or red squirrels, or by larger predators such as skunk, fox, or coyote. Predators account for some mortality in hibernacula (Burger et al., 1992). The role of fluctuating subsurface temperatures within a hibernaculum may play a role in avoidance as well, but this aspect has not yet been investigated for pine snakes.

Elsewhere in the New Jersey Pine Barrens, Burger and Zappalorti (2012) showed that pine snake hibernacula are occupied almost continuously for 26 years; when they are not used, it is usually because they have been breached by a predator. However, that study examined hibernacula that were excavated each year, and computed occupancy of hibernacula, not fidelity by individual snakes. The present study clearly demonstrates that pine snakes that use natural hibernacula (and were not disturbed or excavated by humans), shift hibernacula sites, and do so voluntarily and frequently.

Elsewhere in the range of northern pine snakes (Tennessee), Gerald et al. (2006a, 2006b) reported that four of six radio-tracked pine snakes did not use the same hibernation site the following year, and only two did, confirming that some undisturbed pine snakes reuse the same overwintering sites, but others did not. Unlike pine snakes in the Pine Barrens, pine snakes in Tennessee did not hibernate communally (Burger et al., 1988). That a given hibernaculum can be used for at least 26 years suggests that such sites are optimal and may be limited (Burger and Zappalorti, 2012). Data from the present study showed that snakes may shift sites regardless of whether they previously used natural or human-made hibernacula, but philopatry was significantly higher to natural than to artificial sites for the radio-tagged snakes. Data thus indicate that most pine snakes switch among winter dens, mainly selecting natural hibernacula, suggesting that artificial dens are used, but protecting natural hibernacula should be a higher conservation priority.

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